Answers - preheating feedstocks for extrusion

Answer # 1
Introducing preheated PVC pellets to the extruder is like adding extra length to the screw. The feed end of the screw is not much more that a conveyor and the cold pellets are inefficiently heated. If you have a properly designed screw (and die), with oil cooling, the output can be increased. Also, the profile can be more stress free and the machine can take less energy to move the material from pellets to a uniform extrudate.

If you can increase the RPMs can the screw take more material? There is an optimum speed of a screw. Increasing the speed will do no good with a gravity feed hopper. If you are able to drop more material on the screw with increased speed, there is a good chance the metering section will overheat. This can remedied by increasing the depth of the flight at metering section. This will relieve the over heating and increase the output.

However if you find that the screw will accept no more material by increasing the speed, the next step would be to deepen the feed section. This will result in more material dropping on the screw. With this change, there probably will be more frictional heat generated in the metering section which can be taken care of by deepening the flight depth.

How much to alter a screw would depend of the size, L/D, design of the screw and die and the present performance of the machine.

To summarize:

1. Yes it’s possible to increase the extruder output (plus other benefits) by preheating the pellets — without changing the screws.

2. After making some trial runs on the existing screw, it may be very possible to in crease output with preheated pellets by altering the existing screw.

3. If point 2 is not practical or does not work, a newly designed screw is recommended for the preheated pellets.

- Don Biklen

Answer #2
In single-screw extrusion of rigid PVC . . . what are the benefits of pellet pre heating?

Preheating is a well-known but little-used process factor, except where it is a result of predrying. But preheating by itself has benefits:

a) consistent feed temperature, which helps minimize dimensional variation.

b) faster melting, which may be translated into more output, and may compensate for low residence time and/or less-than-ideal screw design.

c) sometimes faster melting also means better mixing, as the melt is ready for mixing sooner and thus spends more time under mixing conditions.

d) less demand for motor power, but not necessarily less load on the thrust bearing (which depends on head pressure, which in turn reflects die resistance).

e) possible (but not certain) increased friction between pellet and barrel wall. This, in turn, may mean higher output, if:

1. The increased friction gives better "bite" (intake per rpm), AND rate was other wise limited by such intake.

2. The improved bit changes pressure in the feed and early melting zones and improves a surging situation which had been the rate limit.

3. The improved bite allows lower rpm to get the same output. This may mean a lower melt temperature as the screw is turning more slowly. Thus, if overheating and/or down stream cooling were limits to rate, a com promise rpm might be found lower than before, but at a higher output than before.

Remember to be careful with rate-increasing ideas, as the thing you are working on may not be the thing that limits rate.

As for screw design, the basic change made by preheating is the reduction of the energy needed to soften and melt. Therefore, feed zones can be shorter, with the gain used either in compression or metering, or divided between them. This holds for barrier screws as well as standard three-zone screws, but not for the special screws used with grooved barrels.

Preheating is such an easy thing to do, at least on an experimental basis, that it should be tried with existing screws over a range of preheat and rear-barrel temperatures, before any new or altered screw is considered. Then, even if a screw change is indeed indicated, there will be some real data on which to base the change.

- Allan L. Griff

Answer #3
The melting capacity of an extruder is inversely proportional to the energy required to heat each pound of resin from feed temperature (room temperature) to extrudate temperature. A higher feed temperature would require less energy generation from the extruder, consequently more material can be melted by the same amount of energy (from the extruder).

However, a reduction in energy requirement is not the only benefit of preheating. For instance, preheating can solve surging problems by enhancing the melting process in the extruder and reducing the likelihood of plugging the channel with unmelted plastic. Also, as preheating facilitates melting, mixing quality will be greatly enhanced due to the absence of unmelt in the extrudate and the increased residence time in the melt pool. Existing extrusion equipment can immediately benefit from preheating. Since it completes melting earlier than under normal feeding conditions screw speed can be in creased to yield a higher production rate. This will cause melting to be completed closer to the die, as was the case without preheating, and yield an extrudate equivalent in melt quality to that obtained without preheating but at lower production rate.

Naturally, a new screw design can optimize the benefits of preheating. Since a pre heated feed requires less heat for melting, the compression ratio of the screw can be lower and the channel deeper. Furthermore, feed temperature greatly effects resin properties. Prominent among these parameters is the dependence of the coefficient of friction on feed temperature. Feed section geometry should be altered to take full advantage of these changes in resin properties. Subsequently, a change in the feed section of the screw will require alteration in the design of the whole screw.

- Dr. Imrich Klein

Answer #4
The extruder power equals the sum of the energy required to heat the polymer to the melt temperature, the work required to pressurize the polymer, the heat lost (or gained) through the extruder barrel and the mechanical losses in the extruder drive. If you define a well designed screw as one which allows the extruder to run adiabatically at the required rate, temperature and pressure, then you will probably require a different screw for operation with heated pellets than for operation with unheated pellets. You can also expect less energy input in the melting zone of the screw and less extruder power. If the drop in energy input at the melting zone exceeds the energy input in heating the pellets, your melt temperature would tend to be lower and it would be possible to increase thruput by increasing the screw speed. The converse is true if the drop in energy input in the melting zone is less than the energy input in heating pellets.

If you are not using all of the power avail able at your extruder, you should be able to increase rates, with out a change in melt pressure or temperature, through modifications to the screw. Still higher rates should be obtain able by using heated pellets and all of the available extruder power with a well designed screw.

This discussion is limited to mechanical effects rather than any chemical effects related to pellet heating. You also need to retain the free flowing character of the pellet during heating.

- Dr. Kenneth L. Knox

Answer #5
The question specifically asks "What results can I expect from preheating PVC?" Al though nothing is absolute in plastic extrusion, all plastics extrude "better" when preheated, particularly PVC.

First, the plastic should always be fed above the dewpoint of the material. If, for instance, the plastic is stored in a cold area and is brought in directly to the extruder, it can be below the dewpoint and condense moisture which will at best give a bad finish and may even interfere with feeding.

Second, less energy is required for the melting process if the material is preheated. This is a simple heat balance and the results can be significant. This is not a problem for Mr. Hirschberger.

Third, particularly with rigid PVC, the lubrication system behaves differently at different feed temperatures. We have noted that as PVC ages, the compound seems to absorb the lubricant and less is available for processing. In this case, the quality of extrusion is even more enhanced by preheating.

The output rate is generally increased. Since the viscosity is lowered and the effective lubrication increased, a shallower screw can be accommodated without excessive burning. This, in turn means less retention time and a smoother, more fluid output, which may cause problems in sizing. Normally, we don’t change screws, but can speed up the current screw. Screw design is probably optimum, however, and the advantages of even a small improvement can bring such gains that a constant up date should be the major technical program of any extrusion plant.

Powder extrusion is also improved by pre heating. By feeding directly out of the intensive blender, however, the additives may not have sufficient time to be absorbed, contrary to the effect mentioned by aging above. In this case, the power requirement and rate will improve, but the quality of the extrudate is generally poorer.

How much can you preheat. We normally preheat for an hour with 160 degree air. This is safe. However, we have heated pellets and powder up to 200 degrees F. Beyond that, mysterious blockages occur, presumably in the feed section.

- Robert L. Miller

Answer #6
Pellet preheating in a single screw extruder depends on two major factors both of which radically change the rate of output.

Case I. Preheating usually is a major help in increasing the extrusion rate because the normal heat required to be added to the material by frictional and conductional contact with the barrel is already present in the material. Therefore, the pressure increase in the feed and compression sections increases abnormally quickly. This causes the pellets to traverse the metering section quicker, possibly without the time to mix and melt. Therefore, unless some thing is done to increase the back pressure, such as a head valve or finer screen pack, unmelted pellets can find their way into the head or clog the die.

Case II. The second major factor controlling the rate of extrusion is the friction in the feed section relative to the preheated compound. Let’s assume that the lubricant system is relatively low melting, i.e., below the temperature of the preheat. The effect of preheating will allow the lubricant on the surface of the pellet to melt and lubricate, interfering with the feeding and pressure build-up — the net result: significantly lower extruder pressure and output.

Now assume that the lubricant is higher melting than the preheat temperature and is highly compatible with the PVC resin. Under these conditions the preheat aids the rate of extrusion, but not necessarily improves the quality of extrusion (refer to the initial preheating case). Sometimes when the lubricant is very compatible with the PVC, it can improve the quality by acting as a processing aid.

Can the extruder output be increased by preheating when the extruder is not power limited? Mr. Hirschberger asks. If nothing interferes with the interaction of the pellets with the barrel surfaces, the answer is definitely yes.

But the important thing to remember is that the design of the screw normally is not structured for the higher output now obtained, so as mentioned in the first case, unmelted pellets can be expected at the tip of the screw unless the metering section is too shallow to allow the pellets to pass. Then, for shallow metering sections, overheating may result.

There is no question that a different screw design should be used to specifically accommodate the preheating. If the pellets traverse the screw faster, obviously the screw needs to be designed for faster melting. A barrier design helps immensely.

To accommodate a higher output without changing the screw, one must have had a screw which was not being used to the ultimate efficiency, i.e., the melting and mixing occurred earlier in the screw under normal operating conditions; if this condition exists, then the preheat illustrated in Case I will net higher out puts without changing the screw.

To sum up the realistic factors involved with pellet preheating, one must consider more than the design of the extruder screw. A partial list of the factors involved in beneficial preheating are as follows:

1. Rigid PVC formulation

a. Lubricant type

b. Lubricant level

c. Synergistic lubricity

d. Processing aids

e. Type of stabilizer (some act as lubricants).

2. Rigid PVC format

a. Cubes

b. Spheres

c. Oblong pellets

3. Temperature of the Preheat

a. Relative to PVC compound components

b. Barrel heat profile

c. Flight angle

d. Surface finish of the barrel

- David W. Riley

Answer #7
The primary reason for pellet preheating is to remove moisture. Although PVC is not hygroscopic, moisture problems can occur due to water carry-over from strand quench baths or from condensed moisture on the surface of the pellets. Moisture trapped in the melt causes voids which can be detrimental to appearance and impact strength of the product.

A second effect of pellet preheating is that it shortens the fusion time in the extruder due to the substantial amount of heat conducted into the polymer in the hopper. This will in crease the amount of mixing achieved, since mixing begins only after a melt pool is established in the screw channel. The net effect is to improve properties and appearance at the same rate or to allow maintenance of the same properties and appearance at a higher rate.

The best way to predict the effect of pellet preheating is to speed up the extruder and note the effect on the melt temperature, extrudate appearance and properties. If a deep flighted screw is used, melt temperature will climb moderately and the product will have a lumpy non-uniform appearance. A shallow flighted, high work screw will generate excessive stock temperature making handling and cooling the extrudate difficult. Using pellet preheating with the deep flighted screw will allow an increase in output but will cause excessive melt temperature with the shallow flighted screw.

The best performance can be achieved with a given L/D extruder by using pellet preheating in conjunction with a screw that provides sufficient work to attain the desired melt temperature. If a high work screw is being used, one can readily increase the fusion time of the compound to prevent overheating by re-formulating and optimize the performance with pellet preheating. However, if the work input is too low, reformulating to reduce fusion time generally results in a compound cost penalty since additional process aid will be required.

- Leonard F. Sansone

See also:

- Performance of twin screw extruders
- Precision profile extrusion
- PVC testing
- Strand cooling
- Twin screw extruders design and operating characteristics

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